

การเคลื่อนตัวของดินเนื่องจากการจากขูดเจาะอุโมงค์ด้วยหัวเจาะแรงดันดินสมดุลในดินกรุงเทพฯ

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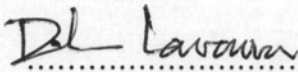
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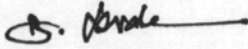
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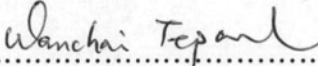
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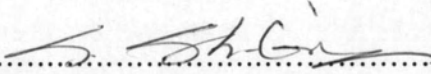
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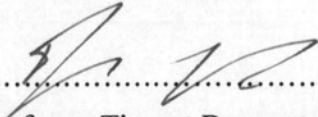
  
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นายชกไต้ ลิม: การเคลื่อนตัวของดินเนื่องการจากขุดเจาะอุโมงค์ด้วยหัวเจาะแรงดันดินสมดุล  
 ในดินกรุงเทพฯ (GROUND MOVEMENT RESPONSE DUE TO EARTH  
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พฤติกรรมทรุดตัวของดินยังคงเป็นคำถามโดยเฉพาะอย่างยิ่งสำหรับการขุดเจาะอุโมงค์ใน  
 พื้นที่เขตเมืองที่มีประชากรอาศัยหนาแน่นและมีอุปสรรคสิ่งกีดขวางมากมายตลอดแนวการขุดเจาะ  
 อุโมงค์ งานวิจัยนี้ทำการศึกษาพฤติกรรมทรุดตัวของดินเนื่องจากการขุดเจาะอุโมงค์และทำการ  
 วิเคราะห์กลับด้วยวิธีไฟไนท์อิลิเมนต์ สองมิติเพื่อการประมาณค่าการทรุดตัวอย่างเหมาะสมในการขุด  
 เจาะอุโมงค์ในกรุงเทพฯ

อุโมงค์ระบายน้ำขนาดเส้นผ่านศูนย์กลางภายนอก 5.55 ม. ในโครงการคลองระบายน้ำแสน  
 แสบ-คลองลาดพร้าว-สถานีสูบน้ำพระโขนง ได้ทำการขุดเจาะด้วยหัวเจาะแรงดันดินสมดุลทั้งการขุดเจาะ  
 อุโมงค์ในชั้นทรายแน่นและดินเหนียวแข็งดินดานที่ความลึกศูนย์กลางอุโมงค์ประมาณ 27.50 ม. ต่ำจาก  
 ผิวดิน ผลการตรวจวัดการเคลื่อนตัวของดินจากการขุดเจาะอุโมงค์สามารถแบ่งได้เป็น 3 ส่วนคือ การทรุด  
 ตัวก่อนถึงหัวเจาะ การทรุดตัวในหัวเจาะ และการทรุดตัวของช่องว่างระหว่างอุโมงค์กับดินภายหลังการ  
 เจาะผ่านของหัวเจาะ (Tail Void) การทรุดตัวที่ผิวดินหลักๆ เกิดขึ้นจากช่องว่างระหว่างอุโมงค์กับดิน  
 ภายหลังการเจาะผ่านของหัวเจาะประมาณ 63-67 % ของการทรุดตัวทั้งหมด สำหรับการขุดเจาะอุโมงค์  
 ระบายน้ำทั้งในชั้นทรายแน่นและชั้นดินเหนียวแข็งดินดาน

การวิเคราะห์การทรุดตัวของดินได้ทำการวิเคราะห์ด้วยวิธีไฟไนท์อิลิเมนต์โดยอ้างอิงพฤติกรรม  
 การพังทลายของดินชนิด Mohr-Coulomb เพื่อยืนยันผลการตรวจวัดการทรุดตัวที่ผิวดินทั้งกรณีการขุด  
 เจาะอุโมงค์ปกติ การขุดเจาะอุโมงค์ผ่านใต้ฐานรากเสาเข็มสะพานคลองตัน และขุดเจาะอุโมงค์ผ่าน  
 ด้านข้างฐานรากเสาเข็มตอมอเตอร์ไฟฟ้า BTS อัตราส่วนระหว่าง Young Modulus กับกำลังรับแรง  
 แฉกของดิน ( $E_u/S_u$ ) จากการวิเคราะห์กลับด้วยวิธีไฟไนท์อิลิเมนต์ พบว่ามีค่าประมาณ 240, 360 และ  
 480 สำหรับดินเหนียวอ่อน ดินเหนียวแข็งปานกลาง และดินเหนียวแข็งมากตามลำดับ ในขณะที่ ค่า  
 Drain Modulus ( $E'_v$ , kN/m<sup>2</sup>) ในชั้นทรายแน่นมีค่าประมาณ  $2000N_{60}$  ผลการประเมินการทรุดตัวที่  
 ผิวดินด้วยวิธี Empirical พบว่าค่าขอบเขตความกว้างของการทรุดตัว ( $i$ ) มีค่าประมาณ  $0.24z_0 -$   
 $0.35z_0$  สำหรับการขุดเจาะอุโมงค์ในชั้นทรายแน่น และเพิ่มกว้างขึ้นเป็นประมาณ  $0.46z_0$  สำหรับการขุด  
 เจาะอุโมงค์ในชั้นดินเหนียวแข็งดินดาน

ภาควิชา.....วิศวกรรมโยธา.....  
 สาขาวิชา.....วิศวกรรมโยธา.....  
 ปีการศึกษา ..... 2549.....

ลายมือชื่อนิสิต.....  
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KEY WORD: EPB SHIELD TUNNELING/ GROUND LOSS/ GROUND MOVEMENTS/ OBSTRUCTIONS/ FE BACK SIMULATION

SOKTAY LIM: GROUND MOVEMENT RESPONSE DUE TO EARTH PRESSURE BALANCE SHIELD TUNNELING IN BANGKOK SUBSOIL.

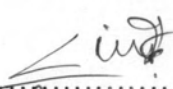
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Ground surface and subsurface movement behaviors remained the questions, especially for the tunnels bored in the densely populated urban area where the several obstructions are usually found along the tunneling route. This research aims to study the behavior of ground surface and subsurface deformations due to tunneling and to do the back analysis based on the 2D FE analysis for an appropriate settlement prediction of tunnel in Bangkok.

An OD 5.55 m flood diversion tunnel of Saensaep-Latphroa Phrakhanong project was bored by means of EPB shield machine in both dense silty sand and hard silty clay layers with centerline at about 27.50 m below ground surface. Half route of the tunnel was bored underneath two bridges and busy roads. The recorded ground surface and subsurface response can be classified into 3 phases as deformation in front of the shield face, deformation within the shield body and deformation due to tail void behind the shield. The major ground surface settlement induced by tail void is about 63-67% of total ground surface settlement for tunneling in both dense silty sand and hard silty clay layers. The 2D FE analysis was carried out based on Elasto-Plastic (Mohr-Coulomb) failure criteria to confirm with ground settlements monitored at different cases of tunneling: tunnel bored without obstructions, under the Klongtan bridge pile foundation and adjacent to the BTS sky train pile foundation. The ratio  $E_u/S_u$  for FE analysis has been confirmed as 240, 360 and 480 for soft clay, medium stiff clay and stiff silty clay layers, respectively. In addition,  $E'(\text{kN/m}^2) = 2000.N_{60}$  can be used for dense silty sand layers. The surface settlement trough width,  $i$ , based on empirical method is found between  $0.24z_0$  and  $0.35z_0$  for tunnel excavated in dense silty layer and it is increased to  $0.46z_0$ , which is wider, for tunnel in hard silty clay.


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Student's signature..... 

Field of study..... Civil Engineering.....

Advisor's signature..... 

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Co-advisor's signature..... 

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## LIST OF SYMBOLS

2D	two dimensions or two dimensional
3D	three dimensions or three dimensional
A	sectional area, total area of settlement trough
BKK	Bangkok
BMA	Bangkok Metropolitan Administration
BTS	Bangkok Mass Transit System
$c$	cohesion
$c_u$	undrained cohesion
CH	inorganic clays of high plasticity
CL	inorganic clays of low to medium plasticity
Co	company
$D$	tunnel diameter
DEM	distinct element method
$d_{eq}$	equivalent thickness of a beam or plate
$E$	elastic stiffness or Young's modulus
$E'$	drained Young's modulus
$E_{50}$	average secant modulus
$E_c$	elastic stiffness of concrete
$E_{oed}$	oedometer modulus
$E_{sec}$	secant Young's modulus
$E_u$	undrained Young's modulus
$E_{ur}$	unloading Young's modulus
FDM	finite difference method
FE	finite element
FEM	finite element method
FVS	Field vane shear test
EPB	earth pressure balance
$g$	acceleration of earth gravity
$G$	shear modulus

$G_{AP}$	gap parameter
$G_p$	physical gap
$G_{sec}$	secant shear modulus
$i$	surface settlement trough width
$I$	moment inertia
IC	inclinometer
JSCE	Japan Society of Civil Engineers
JSST	Japanese standard for shield tunneling
Ltd	limited
$K$	empirical constant of proportionality or surface settlement trough width parameter, coefficient of total lateral earth pressure
$K'$	bulk modulus of soil skeleton
$K_0$	coefficient of lateral earth pressure at rest
$K_w$	bulk modulus of water
km	kilometer
m	meter
$m$	auxiliary elastic constant
ME	extensometer or magnetic extensometer
mm	millimeter
MRTA	Mass Rapid Transit Authority of Thailand
MTX	monotonic triaxial test
$n$	porosity
$N_{60}$	SPT N-value at 60% energy ratio
NATM	new Austrian tunneling method
OCR	overconsolidation ratio
OD	outer diameter
PCL	public company limited
$R$	radius of the tunnel
$r_1, r_2$	distances from the singular point and its image
$R_{inter}$	strength reduction factor of soil-structure interface
$s$	settlement
$s_{max}$	maximum settlement
$S_u$	undrained shear strength
SM-SP	poorly graded silty sand

TBM	tunnel boring machine
$u$	pore water pressure
$u_{3D}^*$	three-dimensional elastic deformation
$u_x$	displacement in $x$ direction
$u_y$	displacement in $y$ direction
$V_s$	volume of the surface settlement trough per unit length
$V_L$	volume loss or ground loss
$x$	transverse distance from the tunnel axis
$z$	depth from ground surface to any subsoil level
$z_0$	depth from ground surface to tunnel axis
$\alpha$	scale factor in centrifuge model testing
$\delta$	relative displacement caused by the ovalization of the tunnel, clearance between tunnel lining and tail skin of a TBM
$\Delta$	thickness of tailpiece or tail skin of a TBM
$\varepsilon$	relative uniform radial displacement of the tunnel surface or uniform radial ground loss
$\varepsilon_s$	shear strain
$\gamma_c$	unit weight of concrete
$\gamma$	total unit weight
$\varphi$	friction angle
$\varphi'$	drained or effective friction angle
$\varphi_u$	undrained friction angle
$\kappa$	Cam-clay swelling index
$\kappa^*$	modified swelling index
$\lambda$	proportional parameter, Cam-clay compression index
$\lambda^*$	modified compression index
$\nu$	Poisson's ratio
$\nu'$	drained Poisson's ratio
$\nu_c$	Poisson's ratio of concrete
$\nu_u$	undrained Poisson's ratio
$\rho$	bulk density
$\rho_w$	water density

$\sigma$	total tress
$\sigma'$	effective stress
$\sigma_0$	initial tress or initial overburden
$\sigma_h$	total horizontal stress
$\sigma'_h$	effective horizontal stress
$\sigma_v$	total vertical stress
$\sigma'_v$	effective vertical stress
$\omega$	workmanship factor
$\psi$	dilatancy angle